control, freeway operations including ramp metering and toll collection, police, transit, and transportation research. Centers incorporating or moving toward collocation include the TransGuide Control Center in San Antonio, the State of Maryland CHART Operations Center, the Montgomery County Traffic Management Center, the Michigan Intelligent Transportation Systems Center in Detroit, and the Houston TranStar Center. The Atlanta Advanced Traffic Management Center is scheduled to be available for the 1996 Summer Olympics.

Few evaluations of integrated facilities are currently available; however, stories from integrated centers and the trend in developing them tell a compelling story about the value of such facilities. The San Antonio TransGuide facility opened in the summer of 1995. The value of an integrated facility was demonstrated the week before the center opened when an industrial plant fire erupted within view of freeway video monitoring. Based on the visibility afforded at TransGuide, the fire was accessed and fought more effectively, possibly saving the lives of several firefighters. Both local police and fire agencies were convinced of the wisdom of their investment in collocation.

APPENDIX H

ARINC, *Spectrum Requirements for Dedicated Short Range Communications (DSRC), Public Safety and Commercial Applications* (July, 1996)

THE FULL TEXT OF ARINC'S REPORT "SPECTRUM REQUIREMENTS FOR DSRC" MAY BE FOUND IN COPIES OF THE APPENDICES ON FILE WITH THE SECRETARY'S OFFICE OF THE FEDERAL COMMUNICATIONS COMMISSION

APPENDIX I

Proposed Changes to FCC Regulations

Appendix I
Proposed Changes to FCC Regulations

A. Part 2 of Chapter 1 of Title 47 of the Code of Federal Regulations is proposed to be amended as follows:

PART 2 - FREQUENCY ALLOCATIONS AND RADIO TREATY MATTERS; GENERAL RULES AND REGULATIONS

1. The authority citation for Part 2 continues to read as follows:

Authority: Sec. 4, 302, 303, and 307 of the Communications Act of 1934, as amended, 47 U.S.C. Sections 154, 154(I), 302, 303, 303(r), and 307, unless otherwise noted.

2. Section 2.106 is amended by adding "MOBILE" to the United States Table, Non-Government column and "Private Land Mobile (90)" to the FCC use designators in the row for 5850-5925 MHz in the table to read as follows:

§ 2.106 Table of Frequency Allocations

* * * * *

International table	United States table		FCC use designators	
* * *	Government	Non-Government	Rule part(s)	Special-use frequencies
		* * * * *		
* * *	5850-5925 RADIOLOCATION	5850-5925 FIXED-SATELLITE (Earth-to Space). MOBILE. Amateur.	PRIVATE LAND MOBILE (90) Amateur (97)	
	806 US245 G2	806 US245		

* * * * *

B. Part 90 of Chapter 1 of Title 47 of the Code of Federal Regulations is proposed to be amended as follows:

PART 90 - PRIVATE LAND MOBILE RADIO SERVICES

1. The authority citation for Part 90 continues to read as follows:

Authority: Secs. 4, 303, 48 Stat. 1066, 1082, as amended; 47 U.S.C. 154, 303, and 332, unless otherwise noted.

2. Section 90.7 is amended by adding a new definition for Dedicated Short Range Communications Service to read as follows:

§ 90.7 Definitions.

* * * * *

Dedicated Short Range Communications Service (DSRCS). The use of non-voice radio techniques to transfer data **over short distances** between roadside and mobile radio units, between mobile units, and between portable and mobile units to perform operations related to the improvement of traffic flow, traffic safety **and other intelligent transportation service applications** in a variety of public and commercial environments. DSRCS systems may also transmit status and instructional messages related to the units involved.

3. Section 90.350 is revised to read as follows:

§ 90.350 Scope.

The Transportation Infrastructure Radio Service is for the purpose of integrating radio-based technologies into the nation's transportation infrastructure and to develop and implement the nation's intelligent transportation systems. It includes the Location and Monitoring Service (LMS) and the Dedicated Short Range Communications Service (DSRCS). Rules as to eligibility for licensing, frequencies available, and any special requirements for services in the Transportation Infrastructure Radio Service are set forth in this subpart.

4. A new Section 90.371 is added to subpart M to read as follows:

§ 90.371 Dedicated Short Range Communications Service

These provisions authorize the licensing of systems in the dedicated short range communications service (DSRCS). DSRCS systems utilize non-voice radio techniques to transfer data **over short distances** between roadside and mobile radio units, between mobile units, and between portable and mobile units to perform operations related to the improvement of traffic flow, traffic safety **and other intelligent transportation service applications** in a variety of public and commercial environments. DSRCS licensees authorized to operate a system in the 5850-5925 MHz band may serve individuals, federal government agencies and entities eligible for licensing in this Part 90.

(a) Each application to license a DSRCS system shall include the following supplemental information:

(1) A detailed description of the manner in which the system will be operated including a map or diagram.

(2) The necessary or occupied bandwidth of emission, whichever is greater.

(3) The data transmission characteristics as follows:

(I) Specific transmitter modulation techniques used;

(ii) For codes and timing scheme: A table of bit sequences and their alphanumeric or indicator equivalents, and a statement of the bit rise time, bit transmission rates, bit duration, and interval between bits; and

(iii) A statement of amplitude-versus-time of the interrogation and reply formats, and an example of a typical message transmission and any synchronizing pulses utilized.

(4) A plan to show the implementation schedule during the initial license term. If the applicant proposes to use an industry standard that is available for the Commission's review and that includes the information required under paragraphs (2) and (3) above, the applicant may certify compliance with the standard in lieu of providing the information required under paragraphs (2) and (3).

(b) DSRCS stations are exempted from the identification requirements of § 90.425; however, the Commission may impose station identification requirements when determined to be necessary for monitoring and enforcement purposes.

5. A new Section 90.373 is added to subpart M to read as follows:

§ 90.373 DSRCS operations in the 5850 to 5925 MHz band

DSRCS systems may be authorized in the 5850-5875 MHz band, subject to the conditions of this section. DSRCS licensees are required to maintain whatever records are necessary to demonstrate compliance with these provisions and must make these records available to the Commission upon request:

(a) DSRCS systems within the band 5850-5925 MHz will be authorized on a co-primary basis with Military Radiolocation and Non-federal Fixed Satellite (Earth-to-Space) Services.

(b) DSRCS systems are authorized on an exclusive basis and must cooperate in the selection and use of frequencies in accordance with § 90.175.

(c) DSRCS systems will be licensed to Public Safety Service Providers, Public Safety Support Providers, or to other entities only for purposes of providing DSRCS.

APPENDIX J

NTIA Form 44,
Certification of Spectrum Support for Intelligent Transportation Systems,
SPS-10757/3 (May 23, 1996)

FORM NTIA-44
(3/91)

U.S. DEPARTMENT OF COMMERCE
NATIONAL TELECOMMUNICATIONS AND INFORMATION ADMINISTRATION

CERTIFICATION OF SPECTRUM SUPPORT

Classification	Control Number
UNCLASSIFIED	

Recipient Agency	System	Stage of Review
USCG (G-TTM)	Intelligent Transportation System	2 - Experimental

Section 1: OPERATING CHARACTERISTICS FOR WHICH SUPPORT IS CERTIFIED

Frequency	Emission	Power	Station Class (Stage 4)	Operating Location
5850 - 5925 MHz	1M0G1D	1 W	FB, ML	USA

Section 2: SOURCE DOCUMENTS

Docket Number	Description of Document	Dated
SPS-10448	Coast Guard Request for Stage 2 System Review	July 20, 1995
SPS-10711	NTIA Preliminary Assessment	March 11, 1996

Section 3: SPS RECOMMENDATIONS

The Spectrum Planning Subcommittee has reviewed this system under the provisions of Chapter 10 of the NTIA Manual. The SPS, noting that this system (1) will not progress beyond Stage 2, and (2) will not provide a safety-of-life function, recommends that:

1. NTIA certify Stage 2 spectrum support for the Intelligent Transportation System.
2. Coast Guard ensure the FHWA is aware that:
   a. This band is allocated to the radiolocation service, and is the subject of ongoing reallocation efforts.
   b. The FCC has recently issued an NPRM to provide for unlicensed NII/SUPERNet operations in the 5150-5350 and 5725-5875 MHz bands.
   c. This system may suffer harmful interference from adjacent and co-channel high-power DoD systems in this band, in addition to harmonics of 2700-2900 MHz radar operations.
   d. The ITS may not be deployed (i.e., made available to the general public) until FHWA performs an analysis that identifies techniques to mitigate the EMI potential from/to other co- and adjacent-band users, and all parties agree that EMC exists.
3. Coast Guard direct that FHWA:
   a. Conduct an analysis to determine potential worst-case interference distances for a set of emitters identified by the DoD.
   b. Perform coordinated testing in areas indicated by the analysis to pose the greatest interference threat to either the DoD systems or the ITS, and provide copies of the test results to the DoD for review.
   c. Limit ITS Stage 2 operations to areas that are determined to be free from interference either to or from the emitters identified by the DoD.

Name/Title of Recommending Official	Signature	Date
Paul C. Roosa, Jr., Chairman Spectrum Planning Subcommittee	Paul C. Roosa	May 23, 1996

Section 4: NTIA CERTIFICATION

The Office of Spectrum Management certifies Stage 2 spectrum support for this system.

This office concurs with the SPS recommendations in Section 3.

Name/Title of Certifying Official	Signature	Date
William D. Gamble Deputy Associate Administrator	W. D. Gamble	May 23, 1996

Downgrading Instructions	Classification	Distribution
	UNCLASSIFIED	IRAC, SPS, FAS

APPENDIX K

ARINC, *Assessment of Potential Interference to the Fixed Satellite Service (FSS) Uplinks from the Proposed ITS DSRC System*

APPENDIX K

Assessment of Potential Interference to the Fixed Satellite Service (FSS) Uplinks from the Proposed ITS DSRC System

1.0 Background

ITS America is currently petitioning the FCC for co-primary user status with the Fixed Satellite Service (FSS) of the frequency band 5.85 to 5.925 GHz. In order to coexist in this frequency band, it must be shown that the emissions from the ITS's proposed Dedicated Short Range Communications (DSRC) System will not adversely affect the uplink of the FSS system. This analysis will show that the interference from the aggregate number of transmitter beacon systems anticipated for DSRC applications will fall within an acceptable limit already budgeted by the FSS.

2.0 Assumptions

Satellite System:

The performance of a satellite link is based upon its carrier to noise plus interference ratio. The total carrier to noise plus interference is calculated from the following equation.:

$$(C/O)_T = [(C/O)_U^{-1} + (C/O)_D^{-1}]^{-1}$$

where:

$(C/O)_T$ = Total carrier to noise plus interference for a satellite systems
$(C/O)_U$ = Uplink carrier to noise plus interference
$(C/O)_D$ = Downlink carrier to noise plus interference

In most satellite systems the uplink carrier to noise plus interference ratio is much greater (by about 10 dB) than the downlink carrier to noise plus interference ratio. This is what is referred to as the system being downlink limited. From the above equation, therefore, the downlink carrier to noise plus interference ratio will be on the same order as the total carrier to noise plus interference ratio. A value of 12 dB was obtained from the Intelsat Intersystem Coordination Manual - Document IICM-316 as the total carrier to noise plus interference ratio of Intelsat's Integrated Digital Service (IDR) using an INTELSAT VIIA satellite. This is a typical service provided by Intelsat and the technical parameters listed in the IICM-316 document are representative of what can be expected of a FSS link. From the 12 dB $(C/O)_T$ value, an uplink carrier to noise plus interference ratio which is 10 dB greater, or $(C/O)_U$ = 22 dB, can be derived.

Using this value for the uplink carrier to noise plus interference, a value for carrier to interference only can be determined using the following equation which describes the uplink carrier to noise plus interference ratio:

$$(C/O)_U = [(C/N)_U^{-1} + (C/I)_U^{-1}]^{-1}$$

where:
$(C/O)_U$ = Uplink carrier to noise plus interference ratio
$(C/N)_U$ = Uplink carrier to noise ratio
$(C/I)_U$ = Uplink carrier to interference ratio

In most satellite systems the uplink is considered to be noise limited rather than interference limited which would mean that the C/I >> C/N. This is a worst case condition for the DSRC system since the interference from the DSRC system would only be allowed to be a small percentage of the total uplink carrier to noise plus interference. For this analysis we will assume that the C/I for the system for which the interference is from the DSRC system will be 13 dB greater than the total $(C/O)_U$ or $(C/I)_U = 22 + 13 = 35$. This represents approximately 5% of the total C/ O budget.

Satellite Equipment Characteristics:

The following equipment characteristics were obtained from the IICM-316 document for an IDR type system used with the INTELSAT VIIA satellite.

Minimum uplink EIRP	46 dBW
Allocated Bandwidth	51 kHz

DSRC System:

There are a number of manufacturers currently supplying equipment for DSRC applications in Europe in the 5.8 GHz frequency range. As an example of a typical DSRC system, we will use the specifications of a system built by GEC - Marconi called the Traffic and Road Information System (TRICS). The TRICS beacon transmitter is being installed in the UK as part of the Road Traffic Advisor Project Demonstration. The beacon systems are typically installed along the roadside with the main beam pointed at the road at a depression angle of 45 degrees as in Figure 1. According to GEC Marconi specifications for the antenna used for the Road Traffic Advisor Project Demonstration, the EIRP in the direction of the horizon or greater are typically 20 dB less than that at boresight. We will use this figure in the current analysis, but future efforts will more precisely quantify this parameter.

DSRC Equipment Characteristics:

The following equipment characteristics were obtained from the GEC Marconi specification with the exception of the maximum EIRP which was increased to 4 W for a larger coverage zone anticipated for some US installations.

Maximum boresight EIRP	6 dBW (4 watts)

Typical EIRP in the direction of satellite uplink -14 dBW (40 miliwatts)
Allocated Bandwidth 6 MHz

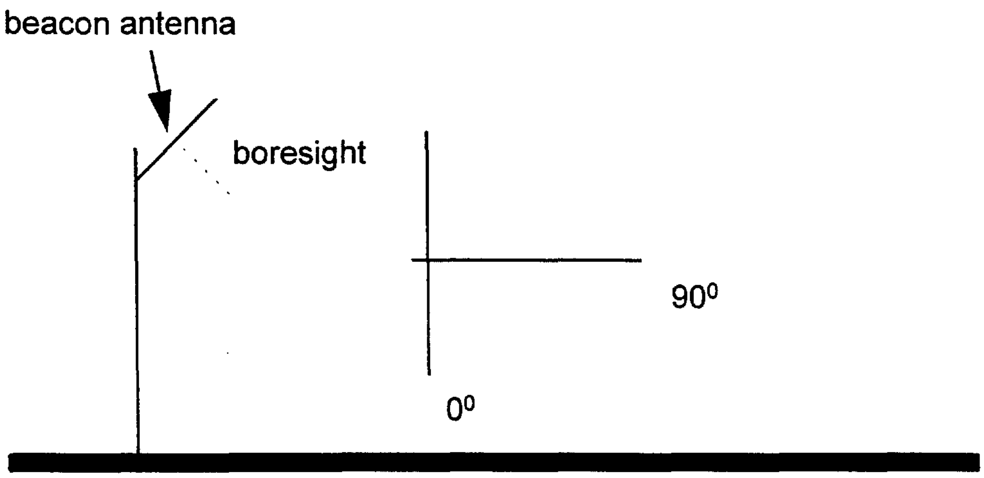

Figure 1: Beacon Antenna Configuration

3.0 Determination of the Total Number of DSRC Transmitters:

Since we are examining the interference from a number of DSRC transmitters into a single satellite uplink channel, we must examine the total power allowed into the uplink channel. From this total power we can determine the maximum number of individual transmitters allowed given this total power. We will use the knowledge of C/I and the equipment characteristics discussed above to determine the maximum number of DSRC transmitters allowed before the C/I threshold is exceeded.

If we assume that the pathloss is the same for a desired signal as for an interfering signal at the satellite receiver, the carrier to interference ratio can be expressed simply as the difference in effective isotropic radiated power (EIRP)of the desired and interfering signals adjusted so that the bandwidths are the same. This is shown in the following equation:

$C/I = EIRP_S - EIRP_I + 10 \log (BW_I/BW_S)$
where:
$EIRP_S$ = EIRP of the desired (satellite uplink) signal (dBW)
$EIRP_I$ = EIRP of the aggregate number of interfering (DSRC) signals (dBW)
BW_I = Interfering signal bandwidth (6 MHz)
BW_S = Desired signal bandwidth (51 kHz)

Using the C/I value of 35 dB discussed above and solving the equation for $EIRP_I$ we obtain:

$EIRP_I = EIRP_S + 10 \log (BW_I/BW_S) - C/I$
$EIRP_I = 46 + 20.7 - 35 = 31.7$ dBW

This value represents the total power allowed by the addition of all of the DSRC signals. Since we know that the signals will not all be of the correct polarization we will introduce a loss of 3 dB. The following equation can then be used to determine the maximum number of transmitters allowed in a 6 MHz channel:

$$EIRP_I = EIRP_{1\text{-}xmt} + 10\log(x) - \text{Polarization mismatch loss}$$

where:
$EIRP_I$ = the total interference power from the aggregate of the DSRC transmitters
$EIRP_{1\text{-}xmt}$ = the EIRP from a single DSRC transmitter
x = the total number of transmitters allowed in the 6 MHz bandwidth

Solving for x we obtain:

$10\log(x) = 31.7 - (-14) + 3 = 48.7$
$x = 74{,}131$ transmitters

This number corresponds to the maximum number of transmitters allowed in a 6 Mhz channel. The ITS, however, is proposing the use of 8 6 MHz channels which would effectively allow 8 times the number of transmitters calculated. Consequently, we conclude that given the parameters described above, a total of 593,048 DSRC transmitters could be placed throughout the US and still not contribute more than 5% of the total noise plus interference budgeted for the fixed satellite service.

4.0 Conclusions

The specific design and operating parameters of DSRC systems for use in the US have not been finalized; indeed, some of the operating characteristics of these systems will likely be established as part of the spectrum allocation rulemaking process, and these may differ from the values assumed in this analysis. However, it is instructive to determine, based upon the parameters used herein, what deployment density could be used to ensure that the number of beacons computed above is not exceeded.

There are 1,069,022 miles of paved non-local roads in the US; 821,004 miles of these are classified as "rural", the remaining 248,018 miles are "urban". Rural highways are expected to have to have no more that one DSRC transmitter every five miles. Urban highways will have higher densities - perhaps as high as one per mile, on average. With that density, there would be a total of 412,218 beacons deployed, well under the "cap" established earlier of 593,048. It is therefore concluded that the DSRC system could be deployed and operated such that it did not interfere with the Fixed Satellite Service uplink if co-primary user status of the 5.85 to 5.925 GHz frequency band were granted.

APPENDIX L

ARINC, *DSRC Standards Discussion*

DSRC Air Interface Discussion

Several air interface specifications are being used for currently implemented DSRC applications. Some of these specifications are proprietary to certain manufacturers. However, a national system of communications needs an open standard that any manufacturer can use. Fortunately, several existing or developing standards that could be applied to DSRC applications also exist. These standards are listed below:

- The California Code of Regulations, Title 21, Chapter 16, Compatibility Specifications for Automatic Vehicle Identification Equipment (Title 21)[1];
- The HTMS specification, VRC Reader-Transponder RF Protocol Specification, May 15, 1995, (HTMS specification)[2].
- The European Committee for Standardization, CEN TC278, Road Traffic and Transport Telematics (RTTT) Dedicated Short-range Communications (DSRC), DSRC Physical Layer using Microwave at 5.8 GHz (CEN TC278)[3]. The CEN TC278 standard is also the candidate for the International Standards Organization (ISO) committee 204 standard for DSRC, (ISO 204).
- The Road Traffic and Transport Telematics (RTTT) Dedicated Short-range Communications (DSRC), DSRC Standard using Microwave in Japan, 26 Sept. 1996, (Japanese Standard)[4].

The Title 21 standard and the HTMS specification currently only specify operations in the 902-928 MHz band and the CEN TC278 prestandard and the Japanese standard specify operations in the 5.8 GHz ISM band. Although, the ISM band only includes 25 MHz of the 5.850 to 5.925 band, all the operational characteristics detailed in the CEN TC278 standard and the Japanese standard can be applied to the entire 5.850 to 5.925 band. However, since the Japanese standard has just recently become available for evaluation, the CEN TC278 specification was used as a basis for determining the performance characteristics of operations in the requested band of operations. Although, the standards bodies have not selected the specifications of the air interface for the 5.850 to 5.925 band to be used in the U.S., selecting a standard will involve much consideration because of the wide variety of choices.

Both the Title 21 and the CEN TC278 use different backscatter techniques for the air interface. However, the backscatter techniques offer easy channel mobility and short reuse distance. The HTMS specification attempts to accommodate multiple air interface specifications

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[1] See the attached California Code of Regulations, Title 21, Chapter 16, Compatibility Specifications for Automatic Vehicle Identification Equipment, nd.

[2] See the attached The HTMS specification, VRC Reader-Transponder RF Protocol Specification, May 15, 1995.

[3] See the attached Draft European Prestandard, Road Traffic and Transport Telematics(RTTT) Dedicated Short-range Communication (DSRC), Physical Layer using Microwave at 5.8 GHz, CEN TC278 WG9 SG.L1, October 1995.

[4] See the attached Road Traffic and Transport Telematics (RTTT) Dedicated Short-range Communications (DSRC), DSRC Standard using Microwave in Japan, 26 Sept. 1996.

including active (amplitude modulation [AM]) and backscatter (Title 21) air interfaces to be incorporated and could provide a 300 foot communication range. However, active devices are still being evaluated for the frequency mobility or frequency reuse distance needed to provide full application coverage on a cost effective basis. In addition, the Title 21 standard is locked into a low data rate of 300 kbps by its subcarrier frequencies and the power levels are set for lane based operation. A significantly modified Title 21 or a new standard is needed to accommodate the desired 600 kbps data rate and the 100 to 300 foot communications ranges. In addition, much more subcarrier, both in channel and out of channel, power level detail is needed to assure adjacent channel operations. The CEN TC278 standard already accommodates 500 to 1000 kbps data rates with the required subcarrier power specifications.

The Japanese proposed standard is an exception to the techniques generally in use. Its active technology transmits 1000 kbps data rates, with downlink duplex and half-duplex uplink operation, on two different 10 MHz channels per link. Although, this standard has sufficient data rate, high reliability, and a short channel reuse distance, it uses 20 MHz per link instead of the 5 MHz that the CEN TC278 standard needs. The number of channels needed to implement the proposed applications using this standard is under investigation.

Therefore, several choices exist for a standard air interface. The CEN TC278 standard with higher power limits and a different operating range, a modified CEN TC278 standard with a 600 kbps data rate, the currently proposed HTMS specification modified to operate at 5.8 GHz or the Japanese standard could all be considered for the standard air interface.

Attachment 1 to Appendix L

Title 21, Chapter 16, Articles 1 through 4 of the California Code of Regulations

TITLE 21,
CHAPTER 16, ARTICLES 1 THROUGH 4 OF
THE CALIFORNIA CODE OF REGULATIONS

CHAPTER 16. COMPATIBILITY SPECIFICATIONS FOR AUTOMATIC VEHICLE IDENTIFICATION EQUIPMENT

ARTICLE 1. SUMMARY OF KEY COMPATIBILITY SPECIFICATIONS FOR AUTOMATIC VEHICLE IDENTIFICATION EQUIPMENT.

Section 1700. Summary. The Compatibility Specifications for automatic vehicle identification (AVI) equipment have been developed around two principal components: a Reader and a Transponder. The minimum role of the Reader is to:

1) trigger or activate a Transponder,
2) poll the Transponder for specific information, and
3) provide an acknowledge message to the Transponder after a valid response to the polling message has been received.

A half-duplex communications system is envisioned where the Transponder takes its cues from the Reader.

The specification is meant to define a standard two way communications protocol and to further define an initial set of data records.

A summary of the key compatibility specifications found in this Chapter are set forth below:

Reader Specifications:

Reader Trigger Signal	33 microseconds of modulated RF
Reader Send Mode (Downlink)	
Carrier Frequency:	915 ±13 MHz (subject to FCC assignment)
Carrier Modulation:	Unipolar ASK (Manchester Encoded)
Data Bit Rate:	300 kbps
No. Data Bits:	Application Specific
Field Strength at Transponder Antenna:	500 mV/m (minimum)

Transponder Specifications:

Technology Type	Modulated Backscatter
Transponder Send Mode (Uplink)	
Carrier Frequency:	Same as Reader Send Mode
Carrier Modulation:	Subcarrier AM
Subcarrier Modulation:	FSK

Subcarrier Frequencies:	600 kHz ± 10% and 1200 kHz ± 10%
Data Bit Rate:	300 kbps
No. Data Bits:	Application Specific
Receiver Field-Strength Threshold:	500 mV/m ± 50mV/m (minimum)

Transponder Antenna:

Polarization:	Horizontal
Field-of-View:	Operation within 90° conical angle.
Location:	Front of Vehicle

Section 1701. Definition of Technical Terms. The following are definitions of technical terms used throughout this Chapter:

(a) AM - Amplitude modulation

(b) ASK - Amplitude shift keying

(c) BCC–Block Check Character

(d) CRC–Cyclic Redundancy Check

(e) CW - Continuous wave

(f) EIRP -effective isotropically radiated power = gain x net power

(g) EM - Electromagnetic

(h) FCC - Federal Communications Commission

(i) FSK - Frequency-shift keying

(j) ID - Device identification

(k) kbps - kilobits per second

(l) kHz–kilohertz (10^3 hertz)

(m) kph–kilometer per hour

(n) MHz – megahertz

(o) Reader - A fixed-position reader, associated transmit and receive (Tx/Rx) antenna(s), and modulation and demodulation hardware and software.

(p) RF-Radio frequency

(q) Transponders - Electronic devices that contain information which can be communicated to the reader.

ARTICLE 2.0 INTRODUCTION.

Section 1702.1. Objectives

This chapter defines the compatibility requirements for automatic vehicle identification (AVI) equipment. Supplemental Agency (e.g., Toll Authority) specifications will detail the technical, environmental, and operational specifics for each site implementation. The immediate mandate for this compatibility specification is for electronic toll collection.

AVI equipment will essentially consist of two functional elements: vehicle-mounted transponders and fixed-position reader units.

The specification is meant to define a standard communications protocol and to further define an initial set of data records. The initial data records are designed for voluntary implementations of electronic toll collection.

It is further envisioned that more complex data records will be developed to handle anonymous transactions, secure funds transfers, information transfers, and other transactions between the Reader and the Transponder that will be defined as needed. Caltrans shall function as the standards monitoring authority to authorize the use of new record types and to assign record type numbers to newly authorized records. Caltrans shall pass this responsibility to an appropriate standards setting organization when one is established and recognized.

Section 1702.2. Organization

This chapter consists of four articles. An overview and summary of the key specifications is given in Article 1. Article 2 presents the objectives and definitions for data codes. Articles 3 and 4 provide specifications unique to the reader and transponder respectively.

Section 1703. Definitions for Data Codes.

(a) *Agency Code*: This 16-bit code field identifies the Agency that has authority to conduct the transaction.

(b) *Byte Order*. Numeric fields shall be transmitted most significant bit first. If a numeric field is represented as multiple bytes, the most significant bit of the most significant byte is transmitted first. This document represents the most significant and first transmitted to the left on a line and to the top of a multi line tabulation.

(c) *Error Detection Code*: The error detection code utilized in the defined records is the CRC-16, with a generator polynomial of $X^{16} + X^{12} + X^5 + 1$. This results in a

16-bit BCC transmitted with each data message. The data field protected by the CRC excludes any preceding header in every case.

(d) *Filler Bits :* Filler bits are used to adjust the data message length to a desired length and shall be set to zero.

(e) *Header Code*: The Header is the first field in each data message for either reader or transponder transmissions and consists of an 8-bit and a 4-bit word for a total of 12 bits. The Header provides a signal that may be used by a receiver to self-synchronize (selsyn) with the data being transmitted, thus the notation Selsyn. The Selsyn signal has binary and hexadecimal values: 10101010 and AA, respectively.

The Header code also provides for a unique, 4 bit Flag that is recognized by a receiver decoder as the end of the Header with the data message to follow. The Flag signal has binary and hexidecimal values: 1100 and C respectively.

(f) *Reader ID Number*: This 32-bit field is used to uniquely identify the reader conducting the transaction.

(g) *Transaction Record Type Code*: This 16-bit code uniquely identifies a specific type of valid transaction between a reader and a transponder. This code uniquely defines the transponder message fields and functions permissible with the transaction type specified by the Polling message as described in Section 1704.5(e)(1). Hexadecimal numbers 1 through 7FFF are set aside for transponder message structures and 8000 through FFFF are dedicated for reader-to-transponder message structures.

(h) *Transaction Status Code*: Used to provide status information to the transponder.

(i) *Transponder ID Number*: This 32-bit code uniquely identifies which transponder is responding to a polling request or is being acknowledged.

ARTICLE 3. READER SPECIFICATIONS.

Section 1704.1. General.

The reader will transmit a RF trigger pulse to activate (turn-on) the transponders. After a time delay, the reader then will transmit an encoded signal, referred to as the Polling message which, upon detection and decoding by the transponder, will provide initial information to the transponder including the type of transaction the reader wishes to conduct.

The reader will then transmit an unmodulated CW, RF signal for the transponder to modulate with a data message while backscattering to the reader. The reader may repeat the Polling-to-backscattering sequence until it obtains an error free data message from the transponder. The reader will then transmit an encoded Acknowledge message to the transponder providing status information and requesting that the transponder not respond to the same polling message again for a fixed time period.

Section 1704.2. RF Carrier Frequency.

The RF carrier frequency shall be taken from the 915 MHz ± 13 MHz range. Specific frequency and bandwidth depend upon pending FCC assignment.

Section 1704.3. Reader Antenna Specifications.

(a) *Reader Antenna Polarizations.*
The reader transmit and receive antennas shall have predominant EM field components that are co-polarized to the horizontal polarization specified for the transponder transmit and receive antennas in section 1705.3(a). Horizontal linear, circular or elliptical polarizations are allowed.

(b) *Reader Antenna Location.:* The reader antenna location is site specific.

Section 1704.4. Reader-To-Transponder Trigger Pulse.

(a) *Trigger Pulse Definition.*
The reader shall provide a wakeup trigger for the transponder. The trigger shall consist of a 33 microsecond long, RF pulse at the assigned carrier frequency that is modulated with a continuous string of ones. The trigger pulse shall be followed immediately by a delay (i.e., no RF transmission) of 100 microseconds duration. The wakeup pulse is intended to signal a dormant transponder to fully activate itself.

(b) *Trigger Pulse Field Strength.*
The required horizontal component of field strength produced by the trigger pulse at the maximum downlink range (site dependent) of the reader shall be greater than 500 mV/m.

Section 1704.5. Reader Communications Protocol.

(a) *AM Modulation Scheme.*
The downlink (reader-to-transponder) modulation scheme shall be unipolar ASK of the RF carrier using Manchester encoding. A data bit '1' is transmitted by sending an RF pulse during the first half of the bit period and no signal during the second half, while for a '0' data bit the reverse order is used; i.e., no signal during the first half of the bit period and an RF pulse transmission during the second half.

(b) *Data Bit Rates.*
The data bit rate for reader-to-transponder messages shall be 300kbps.

(c) *Field Strength.*
The field strength of a reader data message at the transponder shall be greater than 500 mV/m.

(d) *Standard Reader Data Message Format.*
The standard portion of a Reader data message shall consist of a header and transaction record type code. The subsequent length, data content, and error detection scheme shall then be established by the definition for that transaction record type.

(e) *Reader Data Message Formats For AVI.*

There may be several reader-to-transponder data message formats. The format is determined by the Transaction Record Type code sent by the reader. The following is the reader-to-transponder message format presently specified for AVI electronic toll collection applications:

(1) ***Reader Transaction Record Type 1 (Polling Message).*** The Polling message (which follows the 100 microsecond delay after the trigger signal) tells the transponder the type of transaction the reader wishes to conduct. For AVI electronic toll collection applications, Reader Transaction Record Type 1 Polling message also would identify the Agency or toll authority. For AVI applications, the reader-to-transponder Type 1 Polling Message shall be structured using the following ordered data bit fields:

Field Definition	No. Bits	Hexadecimal Value
Header Code		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	8000
Agency Code	16	
Error Detection Code	16	
Total:	60	

(2) ***Reader Transaction Record Type 2 (Acknowledge Message).*** A reader-to-transponder acknowledge data message shall be provided to inform specific transponders that they have been successfully processed and to stop responding to further identical reader polling requests. The acknowledge message is used to terminate the transaction, and is only sent if the transaction is successfully completed. Reader Transaction Record Type 2(Acknowledge Message) shall consist of the following ordered data bit fields:

Field Definition	No. Bits	Hexadecimal Value
Header		
Selsyn	8	AA
Flag	4	C
Transaction Record Type Code	16	C000
Transponder ID Number	32	
Reader ID Number	32	
Transaction Status Code	16	
Error Detection Code	16	
Total:	124	

(f) *Reader End-of-Message Frame.*
The End-of-Message signal for reader-to-transponder data messages shall consist of a minimum of 10 microseconds of no RF carrier signal. Transponder decoders shall have the ability to detect this condition as an invalid Manchester code.

Section 1704.6. Reader Field Strength For Modulated Backscattering.

The electric field strength produced by a reader is a function of the EIRP. The EIRP required to detect a modulated backscattered RF signal from a transponder with a reasonably high signal-to-noise ratio is determined by the maximum range to the transponder and the detection sensitivity of the reader receiver plus any gain margin. If the overall gain characteristics of the transponder were held constant, the required EIRP then becomes site dependent.

The electric field strength to accomplish modulated backscattering is expected to be lower than that required for triggering a transponder or for sending a reader data message. Sensitive reader receivers likely will be necessary, however, such as that obtained with homodyne or heterodyne technology.

ARTICLE 4. TRANSPONDER SPECIFICATIONS.

Section 1705.1. General Description.

Transponders will be encoded with unique identification data together with other coded data as described in this section. On passing through any AVI reader zone, the transponder will provide the coded data to the reader only on receipt of a valid reader polling command. Transponders must be capable of being turned on and off and of two-way data communications. Transponders may be portable.

Section 1705.2. Transponder RF Carrier Frequency.

The transponder RF carrier frequency in a backscatter system is identical to that used by the reader; the frequency will be in the range of 915 MHz $\pm$ 13 MHz. The transponder shall be capable of operating over the full $\pm$13 MHz band to allow site flexibility in reader implementation.

Section 1705.3. Transponder Transmit and Receive Antennas.

(a) *Antenna Polarizations.*
The transponder transmit and receive antennas shall have EM field components that are predominantly horizontally polarized transverse to normal traffic flow. Horizontal linear, circular or elliptical polarizations are allowed.

(b) *Antenna Field of Views.*
The transponder transmit and receive antennas shall have a field of view which is a 90° cone in front of the vehicle. The projection of the horizontal component of the cone's axis shall be parallel to the lane and the vertical component of the cone's axis shall be 35° above horizontal.

Section 1705.4. Transponder Activation.

A transponder shall be fully activated and ready to decode the Polling message from the reader within 100 microseconds of receipt and detection of a 33 microsecond long modulated RF trigger pulse from the reader. The transponder receiver shall be capable of recognizing and acting on a trigger signal and polling message when the free-space field strength at the transponder location exceeds 550 mV/m and will not respond to field strengths below 450 mV/m (Electric field strengths are to be measured in free-space and in the absence of any vehicles). After completion of the Polling message, the transponder shall begin modulating and